# Towards a Standard Method for Life Cycle Assessments of Wastewater Treatment

**Corominas, Ll; Foley, J; Guest JS, JS; Hospido A, A; Larsen, Henrik Fred; Shaw, A**

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# Towards a Standard Method for Life Cycle Assessments of Wastewater Treatment

Ll. Corominas, J. Foley, J.S. Guest, A. Hospido, H.F. Larsen, A. Shaw

**Watermatex 2011, 20th June San Sebastian (Spain)**

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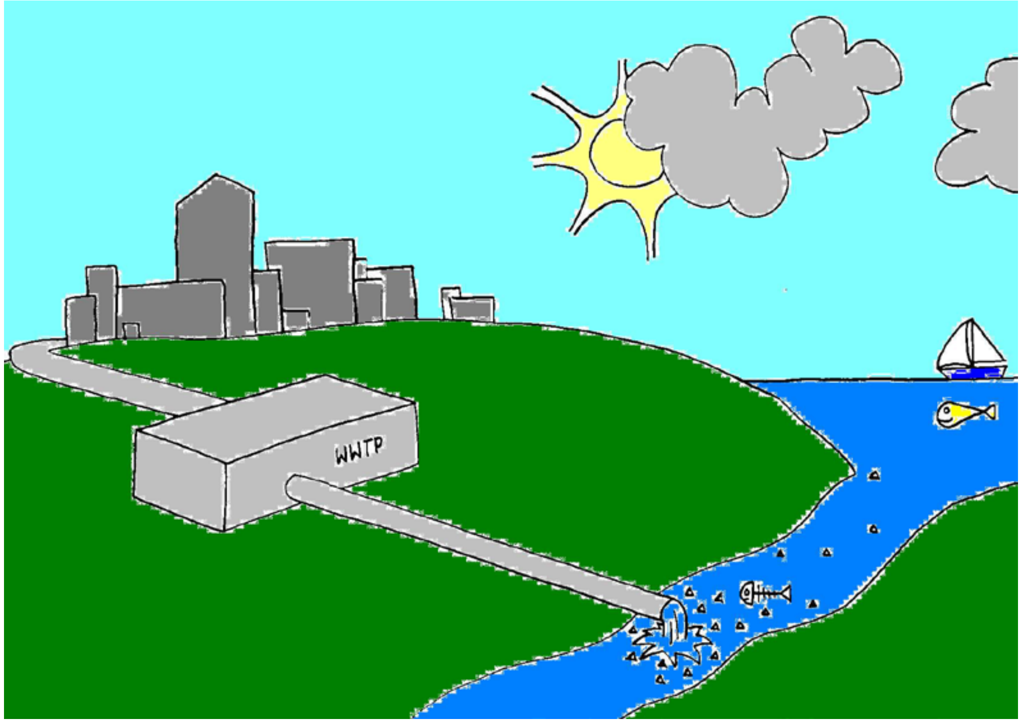
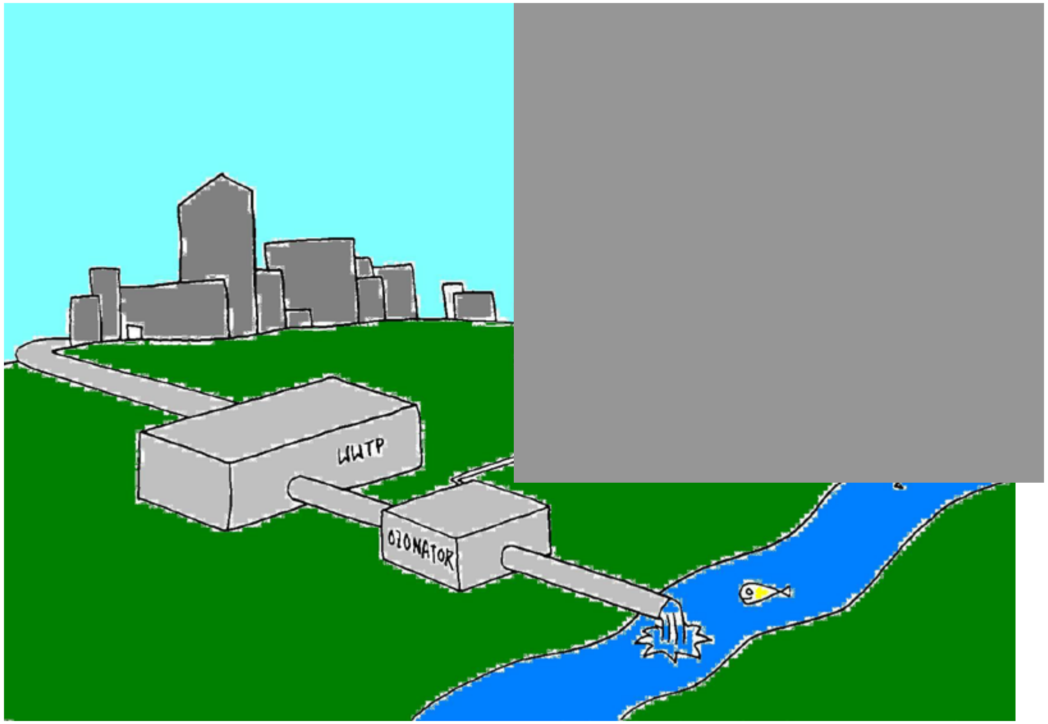
# Life Cycle Assessment




Taken from H.F. Larsen

# Life Cycle Assessment




Taken from H.F. Larsen

# Problem statement

- 1960s: Beggining of this technique
- 1990s: Pressure to standardize → ISO 14040 and 14044
- 2010s: Increase of popularity

↓

Increase of information: databases
Software tools, models, etc

# Problem statement

In WASTEWATER field

- 1990s: Flückiger and Gubler (1994); Emmerson et al. (1995); Fahner et al. (1995); Zimmermann et al. (1996); Roeleveld et al. (1997)
- Until now, about 41 published papers in peer-reviewed journals (+ conference papers)

It is now time to make a review
What have we learned
Were should we go?

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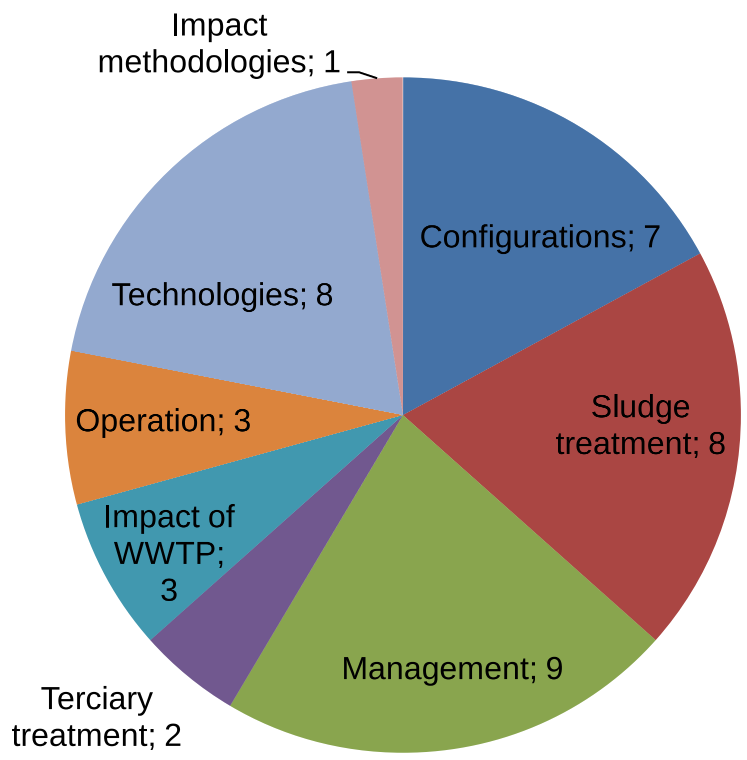
# What have we learned?

- Applications



# What have we learned?

- Boundaries

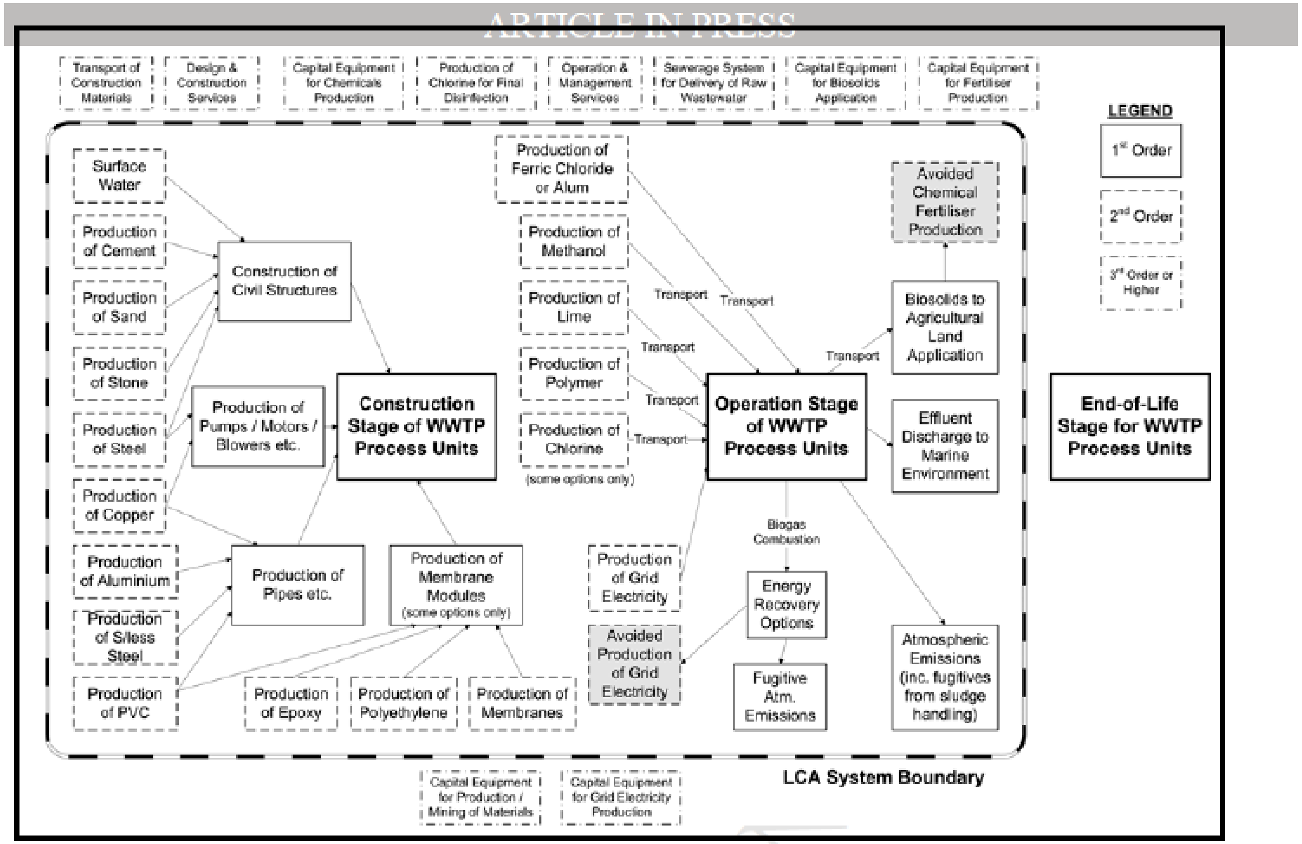



**Figure 2.** System boundary for life cycle inventory of WWTP scenarios

# What have we learned?

- Main Outcomes

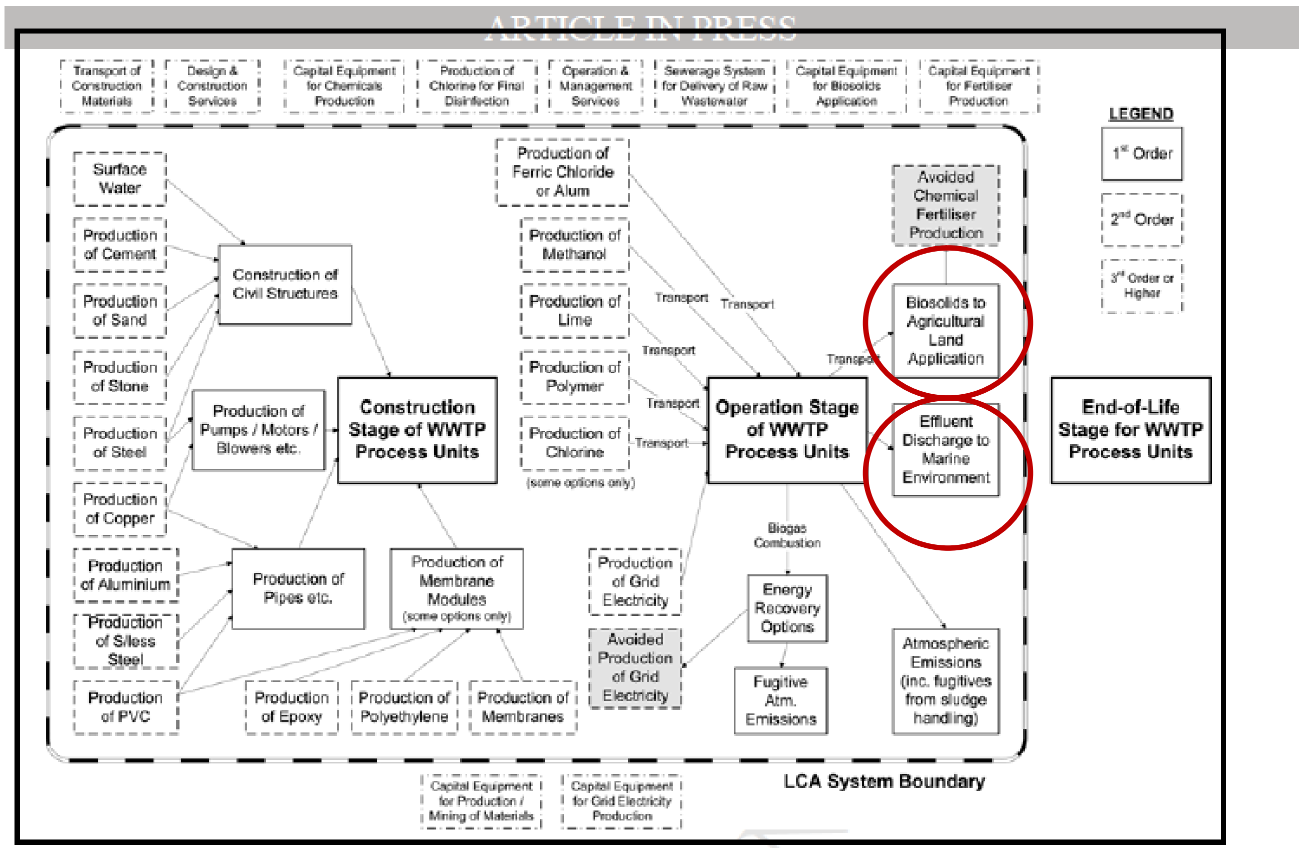



**Figure 2.** System boundary for life cycle inventory of WWTP scenarios

# What have we learned?

- Outcomes
  - Impact of WWTP → water discharge and sludge application
  - Technologies → Avoided vs induced impact (constructed wetlands and sand filtration appropiate)
  - Configurations → Better N removal but Resources depletion, global warming, acidification, human toxicity
  - Operation → Better N and P removal and increase energy efficiency

# What have we learned?

- Outcomes
  - Separation systems (urine) have environmental advantages (avoided fertilizers)
  - Sludge treatment → Anaerobic digestion combined with electricity production. Incineration and land application are acceptable (but minimization of heavy metals from sludge)
  - Impact methodologies → For GHG emissions, acidification, eutrophication, resource depletion not a critical issue

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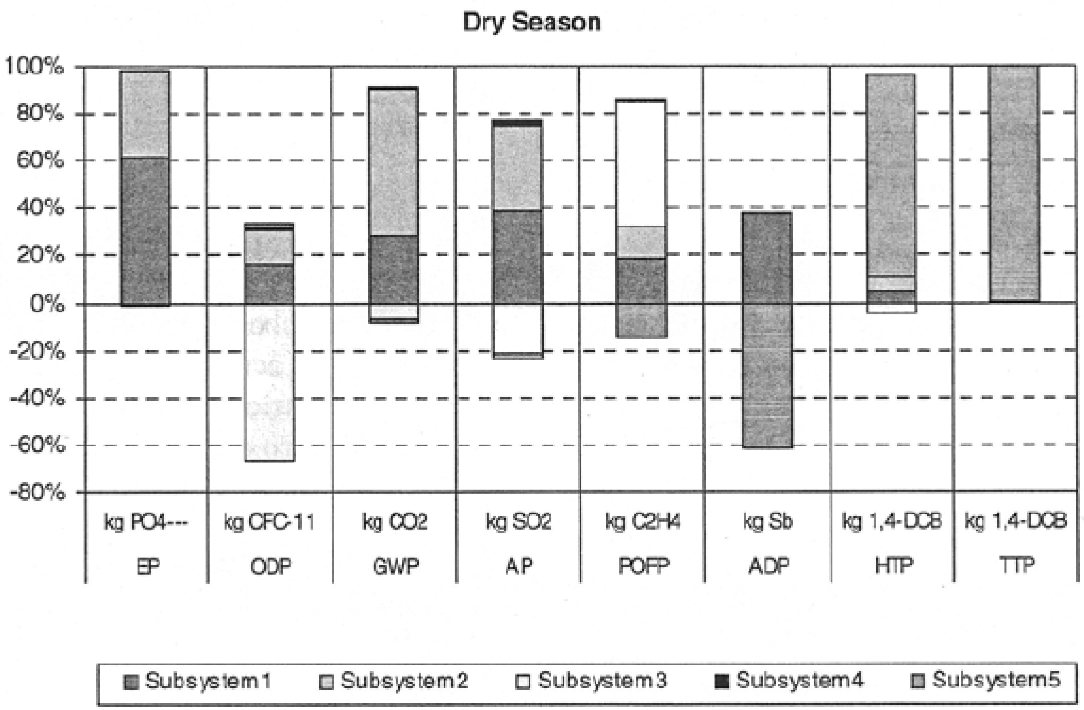
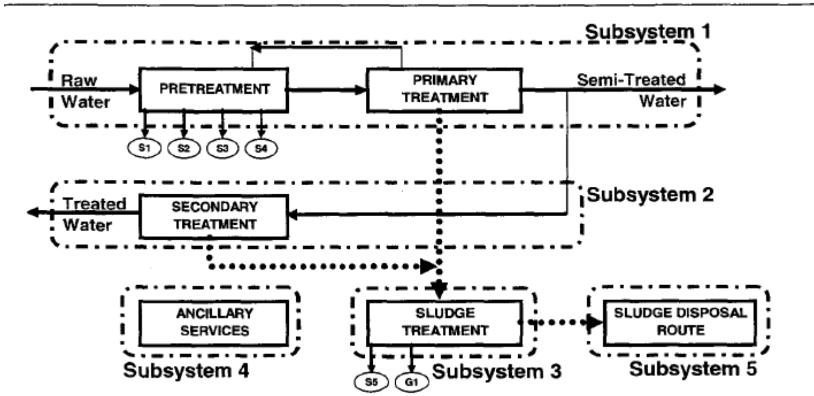
# What have we learned?

*WWTP impact*



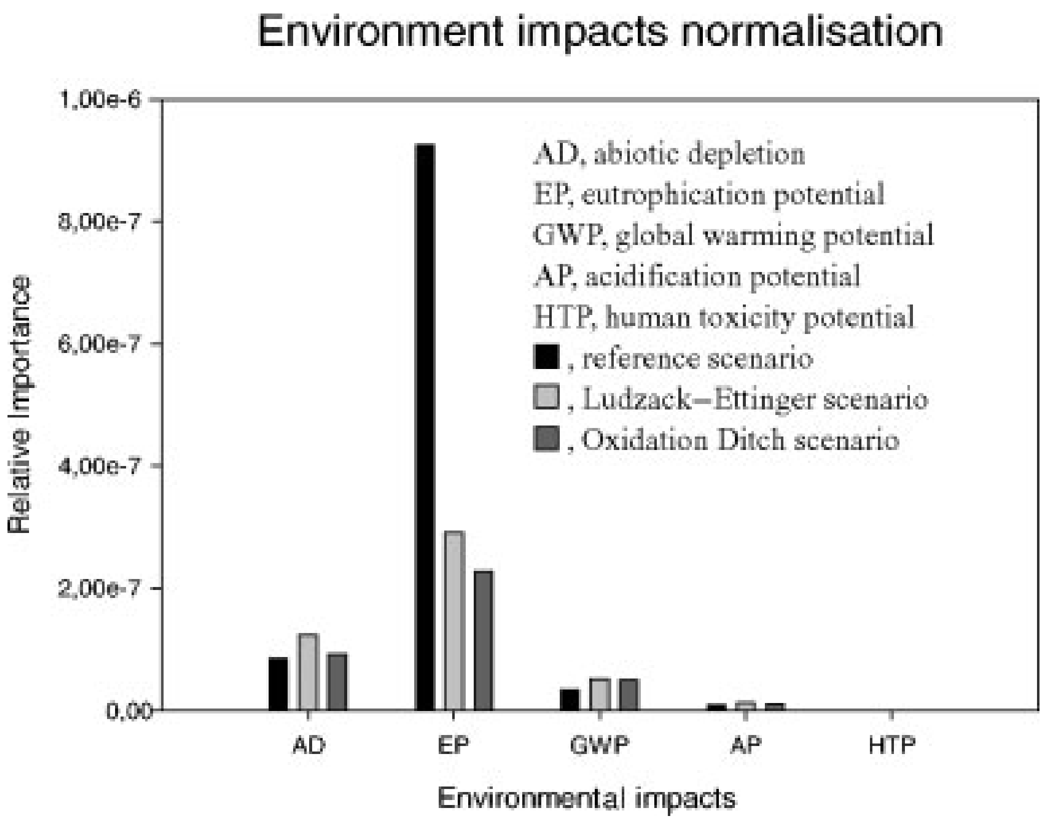




Hospido et al., 2004

**Fig. 2:** Characterisation profiles for both Functional Units. Subsystem 1 is represented in dark grey, subsystem 2 in light grey, subsystem 3 with dots, subsystem 4 in black and subsystem 5 with oblique lines

# What have we learned?

*Configurations*




Vidal et al., 2002

# What have we learned?

## *Technologies*

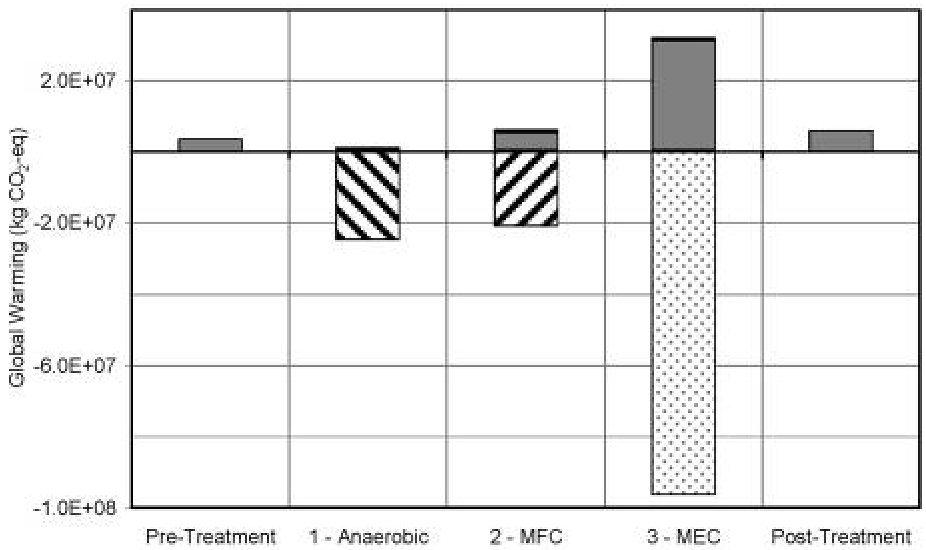



**FIGURE 4. Selected midpoint life cycle impact assessment results, disaggregated into the following: "Con.", construction phase; "Op.", operational phase (i.e., power, chemicals, transportation); "Av. Gas", avoided natural gas from operational phase of anaerobic reactor (Option 1 only); "Av. Elec", avoided electricity from operational phase of MFC (Option 2 only); "Av. H2O2", avoided AO hydrogen peroxide from operational phase of MEC (Option 3 only); and "Sludge", sludge dewatering and disposal from operational**

**phase. The results are expressed in terms of a reference unit for each environmental impact category (e.g., kg CO2-eq for global warming, kg C2H3Cl-eq for carcinogens). Positive values indicate an adverse environmental impact (i.e., the higher the value, the worse is the impact), and negative values indicate an environmental benefit.**

Foley et al., 2009

| | | |
|---|---|---|
| Con. | Op. | Av. Gas |
| Av. Elec. | Av. H2O2 | Sludge |

# What have we learned?

*Sludge treatment*

# Discrepancies

- Inclusion/ exclusion of infrastructure

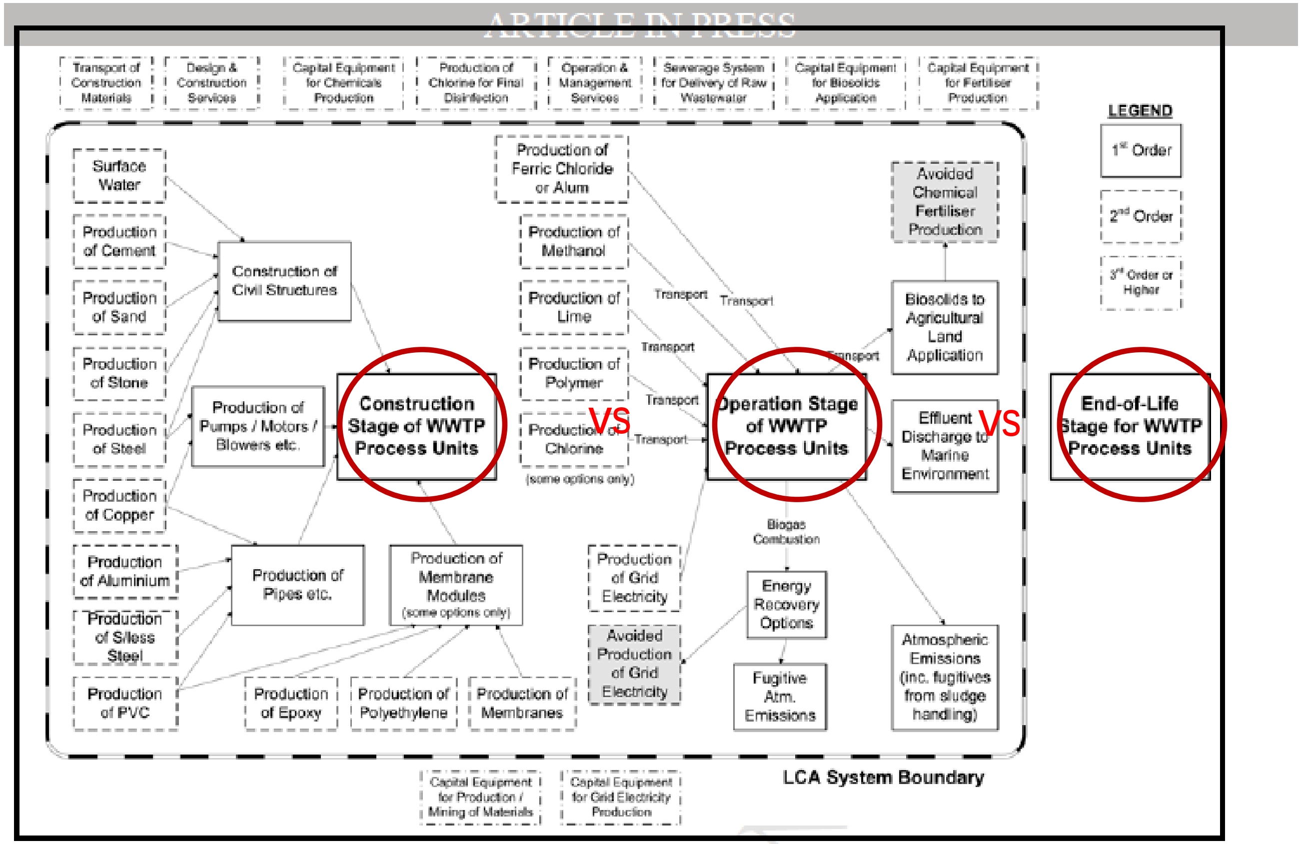
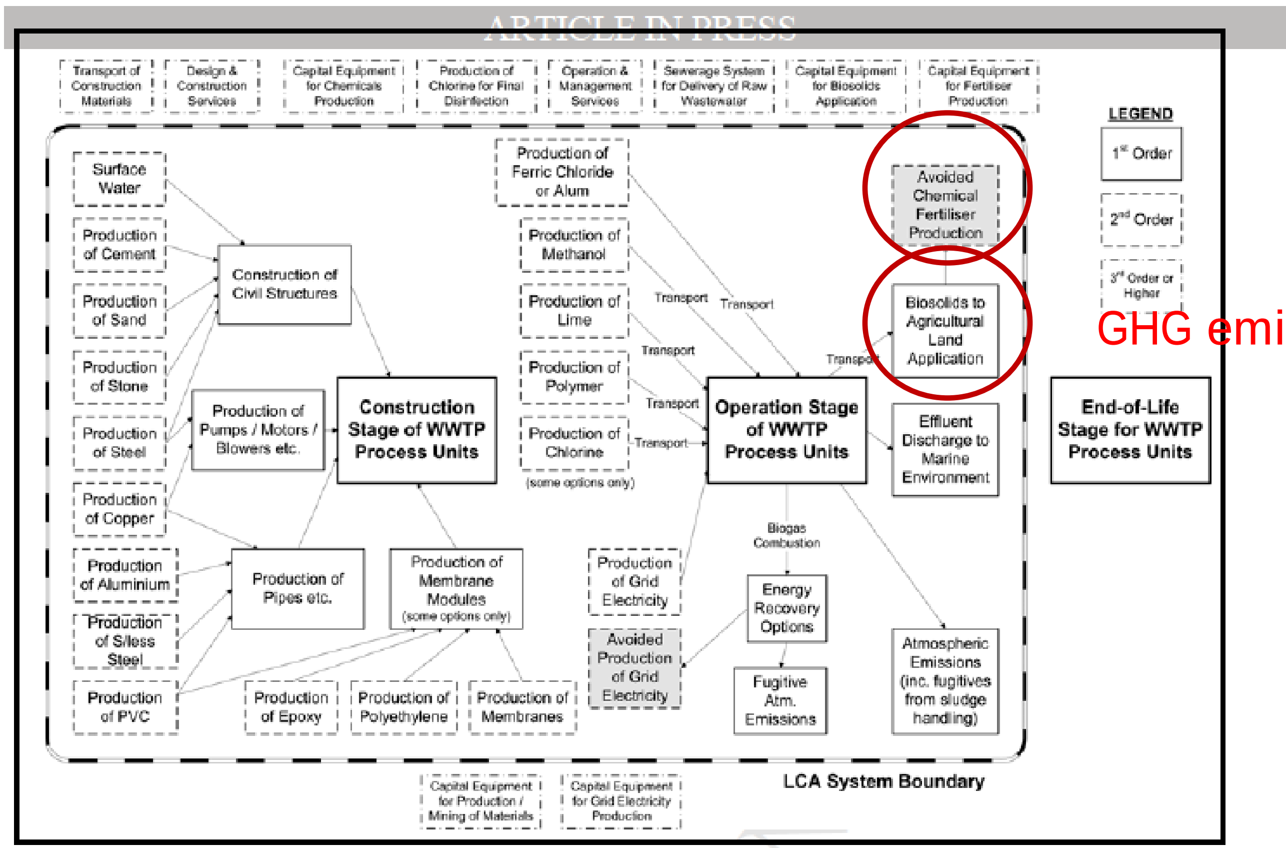



**Figure 2.** System boundary for life cycle inventory of WWTP scenarios

# Discrepancies

- The importance of including disposal of waste

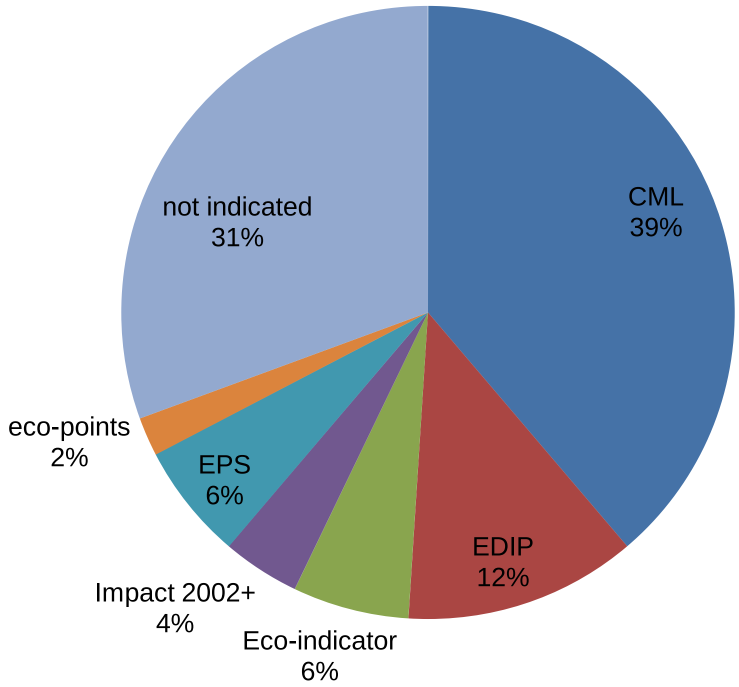



GHG emissions?

**Figure 2.** System boundary for life cycle inventory of WWTP scenarios

# Discrepancies

- Selection of impact methodology



# Discrepancies

- Selection of categories

| | Nº papers including category | Nº CML papers including category | Nº CML papers indicating relevant category |
|---|---|---|---|
| Global warming potential | 43 | 16 | 7 |
| Acidification potential | 27 | 15 | 6 |
| Freshwater eutrophication potential | 25 | 15 | 8 |
| Marine eutrophication potential | 3 | 2 | 1 |
| Human Toxicity | 19 | 11 | 4 |
| Terrestrial eco-toxicity | 18 | 10 | 6 |
| Photochemical oxidation | 19 | 12 | 3 |
| Fresh water eco-toxicity | 14 | 6 | 5 |
| Marine eco-toxocity | 6 | 4 | 3 |
| Fossil energy depletion | 17 | 12 | 3 |
| Material depletion | 7 | 2 | 1 |
| Ozone layer depletion | 14 | 9 | 2 |
| Land Occupation | 2 | 1 | 0 |
| Others | 8 | 2 | 0 |

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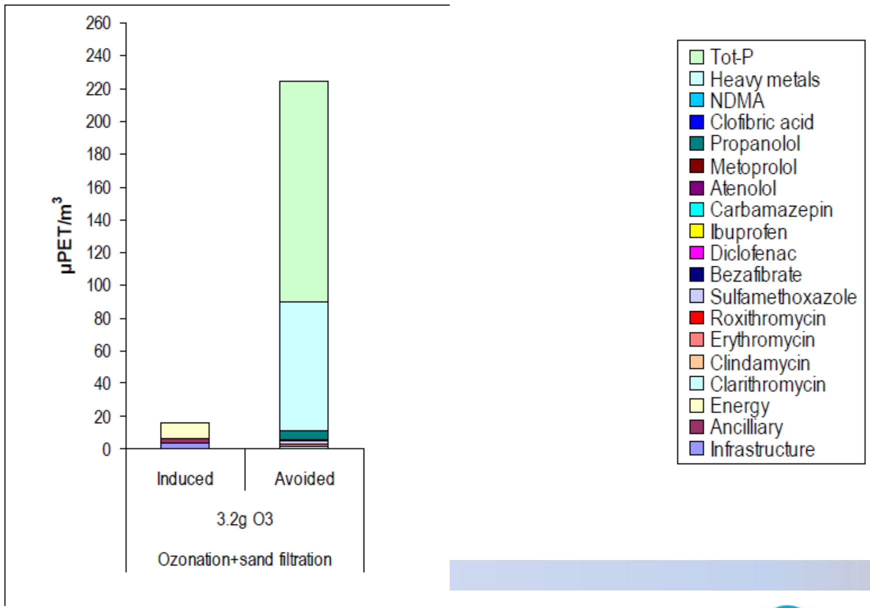
# Where should we go?

- Developments in toxicity-related categories

Environmental sustainability profiles; ozonation + sand filtration
(including both metal and phosphorus removal)
(31 micropollutants + P (only significant ones shown); weighting factor = 1 for all impact categories)




Larsen et al., 2010

# Where should we go?

- Provide local factors, e.g. eutrophication

Table 4 Characterization factors for N and P contained in wastewaters

| Substance ($j$) | Water area ($i$) | $\gamma_i$ | $\varepsilon$ | $\mu_{j,i}$ | $Equj$[a] | $C_{j,\mathrm{wastewater},i}$[a] (Eq.4) |
|---|---|---|---|---|---|---|
| N | Maritime waters[b] | 0.80 | 0.7 | 1 | 0.42 | 0.24 |
| | Freshwaters | 0.80 | 0.7 | 0[c] | 0.42 | 0.00 |
| P | Ocean | 0.87 | 1 | 0[c] | 3.06 | 0.00 |
| | Freshwaters + rias | 0.87 | 1 | 1 | 3.06 | 2.66 |

[a] Expressed as kilogram $PO_4^{3-}$ equivalent per kilogram substance $j$ emitted

[b] Maritime waters = ocean + rias

[c] The ocean is considered N limited and the freshwaters P limited

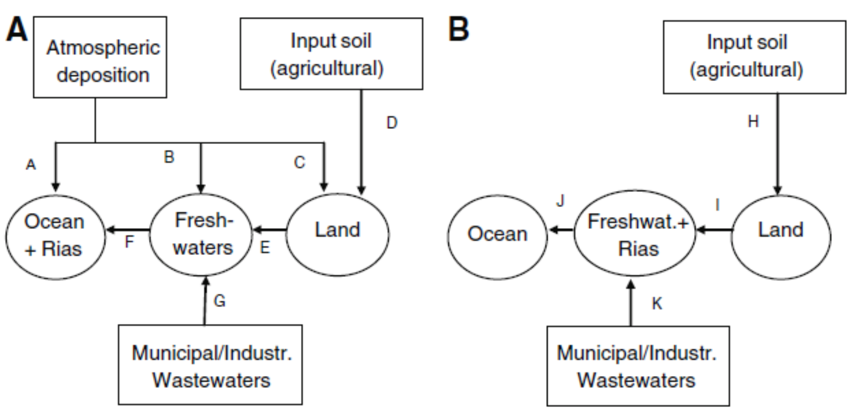



Fig. 2 Principal pathways considered for N (a) and P (b) transport in Galicia

Gallego et al., 2010

# Where should we go?

- Better data quality (evaluation of uncertainty)

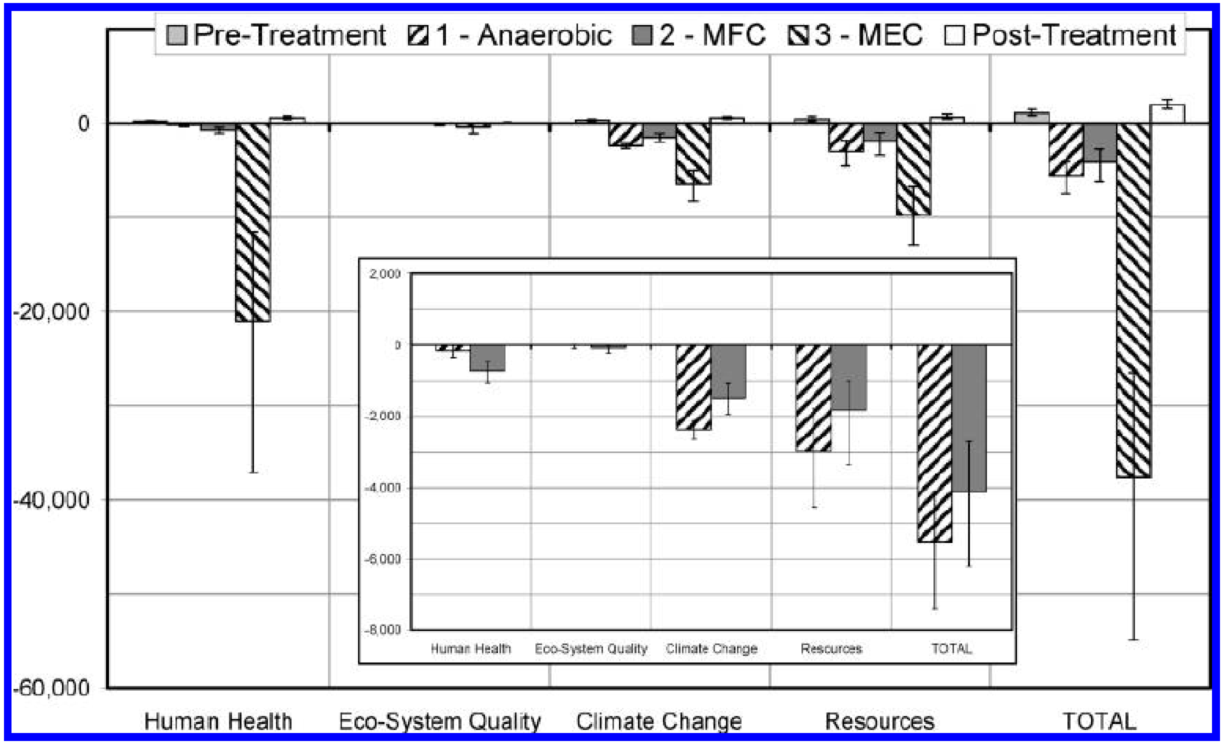



**FIGURE 6.** Comparison of IMPACT 2002+ normalized end-point scores, including Monte Carlo analysis uncertainty ranges. Inset shows a magnification of the comparison between Option 1 (anaerobic) and Option 2 (MFC). Error bars (95% confidence interval) indicate the uncertainty inherent in the background inventory data for the three options. This uncertainty range is generated using a Monte Carlo analysis (1000 runs) on each option in SimaPro.

# Where should we go?

- Decission-making (link with economic and social criteria)

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